Estimating Water Quality Within Multi-use Catchments, Northern Murray-Darling Basin.

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SUMMARY

Blooms of toxic blue-green algae in the Murray-Darling Basin (MDB) have caused community groups in the catchment to seek methods of reducing the problem. A generic spatial modelling framework capable of interactively linking catchment water quantity and quality models and a GIS for analysis of the effects of changing land use and management practices on the quality of runoff for large creek systems (up to 10 000 km^2 in area) is being developed. Both ground and surface waters for a network of catchments of different land use, soil types and sizes in the Queensland portion of the MDB are being monitored to provide data for calibration of the models. A method of displaying model output three dimensionally is being produced. This will allow catchment managers to make more informed decisions on appropriate land use and management practices in the MDB.

INTRODUCTION

The Murray-Darling Basin (MDB), the largest river system in Australia, had many blooms of blue-green algae in its waters during the summer of 1991-2, with a bloom over a 1 000 kilometre stretch of the Darling River being the worst (Johnstone, 1992). These blooms have several detrimental effects including death of domestic stock, extra treatment or closure of domestic and irrigation water supplies and loss of recreational use (Murray-Darling Basin Ministerial Council, 1993).

Algal blooms are caused by a combination of a number of factors with the main ones being high concentrations of plant nutrients in the water, slow flowing or stagnant water, warm water temperature and sunlight. The first three of these can be manipulated .to some extent by human activity. Phosphorous (P), the most influential nutrient, and Nitrogen (N), arise from concentrated or point sources such as sewerage treatment plants and intensive livestock industries and diffuse sources such as in runoff from urban areas, agricultural land and geological erosion. Instream flow is dependent on natural rainfall/runoff processes and management of any impoundments on the stream. This latter item can also influence water temperature.

Any improvement in the situation requires input by those controlling land use and management practices within a catchment on a whole catchment basis. This is best carried out through the informed action of individual users and managers of the catchment resources. The Integrated Catchment Management strategy (Queensland Department of Primary Industries, 1991) and similar strategies are suitable mechanisms for fostering the necessary changes. However, implementation of change requires identification of opportunities for reducing the problem, awareness of these by catchment managers and the adoption of effective management practices.

The work reported on in this paper is aimed at producing information on issues identified by Johnstone (1992) which should benefit the catchment managers in their search for implementation of possible control practices. Those issues include:

- definition of nutrient contribution and composition from diffuse sources.
- measurement of nutrient export from land use activities and effect of changed management practices.
- development of a generic Decision Support System (DSS) to facilitate the development of catchment nutrient management plans.
- the integration of Geographical Information Systems (GIS) with the DSS.
- the development of a program of community education relating to algal blooms.

The key objective of this work is to develop and put in place a generic spatial modelling framework capable of interactively linking simulation models and a GIS for analysis of the effects of changing land use and management practices on the quality of runoff for large creek systems (up to 10 000 km^2). This requires:

- selection, calibration/validation of models suitable for the prediction of catchment water quality over a range of scales.
- a method of rapidly entering data into a format used by those models and presenting output in an unambiguous and easily understood manner.
- interaction with catchment managers, particularly the Catchment Coordinating Committees for each of the four catchments outlined on Map 1 and explained in Queensland Department of Primary Industries (1993).

The framework will house models capable of predicting the water balance for the main land uses in a catchment and routing runoff and associated pollutants through the stream network and into groundwater all linked to GIS for rapid data input and display of results. This is being built notionally for catchments within the Queensland portion of the MDB (Map 1) but will have application elsewhere.

LAND USE EFFECTS

To make informed decisions on the appropriate land use and management within a catchment, the users/managers need reliable prediction of the effects of different land use and management on the quality of water in the catchment. Field experimentation to obtain that information is impossible in terms of cost. Computer simulation is the only practical alternative. What is required is running a model - or linked models - capable of predicting water quantity and quality over a long rainfall record. Long term simulation is necessary to overcome the variability in runoff and erosional events in the rural environment of south-east Queensland as shown by Wockner and Freebairn (1991).

Most of the larger catchments in the area of interest are comprised of many small contributing catchments each of which may have different land uses depending on factors such as soil type, topography, market access, etc. The different land use and management regimes affect the volume and rates of surface and groundwater flows. Those differences may also affect the concentration of pollutants both dissolved and attached to particles in any runoff. The amount of pollutants moved into and through flow networks depends on the supply and transport mechanism. Soil type, in relation to its erodibility, and any fertiliser inputs affect the amount available for movement. Erosional and transport mechanisms and their relative importance vary with flood size and position within a catchment. Thus, to determine pollutant movement in these larger catchments it is necessary to know the contributions via runoff and deep drainage from each of the contributing catchments and their combined effect at increasing scales of aggregation.

Surface Water Quality

A point water balance model able to be used for a variety of land uses and managements such as that of Littleboy *et al* (1989) will be used to predict runoff and deep drainage volumes. Routing of surface runoff and associated pollutants through the stream network will be carried out using a suite of models each applicable to a range within a continuum of increasing catchment size.

These models will have to be able to cover the main land uses within the Queensland portion of the MDB as well as point sources.

The main land uses in that area are sheep and cattle grazing, 88.5% of the area: cropping , 4.2% : and forestry, 3% (Queensland Department of Primary Industries, 1993). There are several urban centres as well as piggeries, feedlots and other intensive livestock enterprises which constitute point sources.

For confidence in output, local validation and calibration of the models will be necessary. The QDPI has collected hydrologic and sediment data for agricultural catchments in the Queensland portion of the MDB for 15 years (Titmarsh *et al*, 1991). However, there is little data available on nutrients in that runoff and associated sediments.

A network of unit catchments, based on single land use and soil type and covering the main soil type/land use combinations present in the area, is being instrumented to obtain necessary data. This network covers the five main soil types in the Queensland portion of the MDB as outlined by Wylie (1993), basaltic derived cracking clays, grey clays supporting Brigalow, *Acacia harpophylla*, red brown earths supporting Poplar Box, *Eucalyptus populnea*, red earths growing Mulga, *Acacia aneura*, and solodics. The general features of the catchments are outlined in Table 1 and their location given on Map 1.

As catchments increase in size, in-stream processes dominate the movement of pollutants as opposed to the influence of overland and rill flow processes in small catchments. The understanding of how this affects pollutant levels in runoff necessitates the monitoring of pollutant movement through sets of nested catchments. Several sets of nested catchments are being instrumented for this purpose (Table 1, Map 1).

Groundwater Quality

Substantial downward fluxes of water below the root zone in cropped lands can occur (for example 20-30 mm y^{-1}; Thorburn 1991, Kennett-Smith *et al.* 1994). Plant nutrients and other chemicals (for example pesticides) may be carried with this water. Streams and rivers interact with groundwater bodies, providing an additional pathway for the chemicals to enter surface waters. If there are substantial concentrations of the chemicals at the bottom of the root zone due, for example, to the inefficient application of fertilisers, there is potential for movement of these to groundwater bodies and into streams., There is little information on downward fluxes of water and associated chemicals in cropped lands. This is especially true for the clay soils which support most of the cropping carried out in the northern part of the MDB.

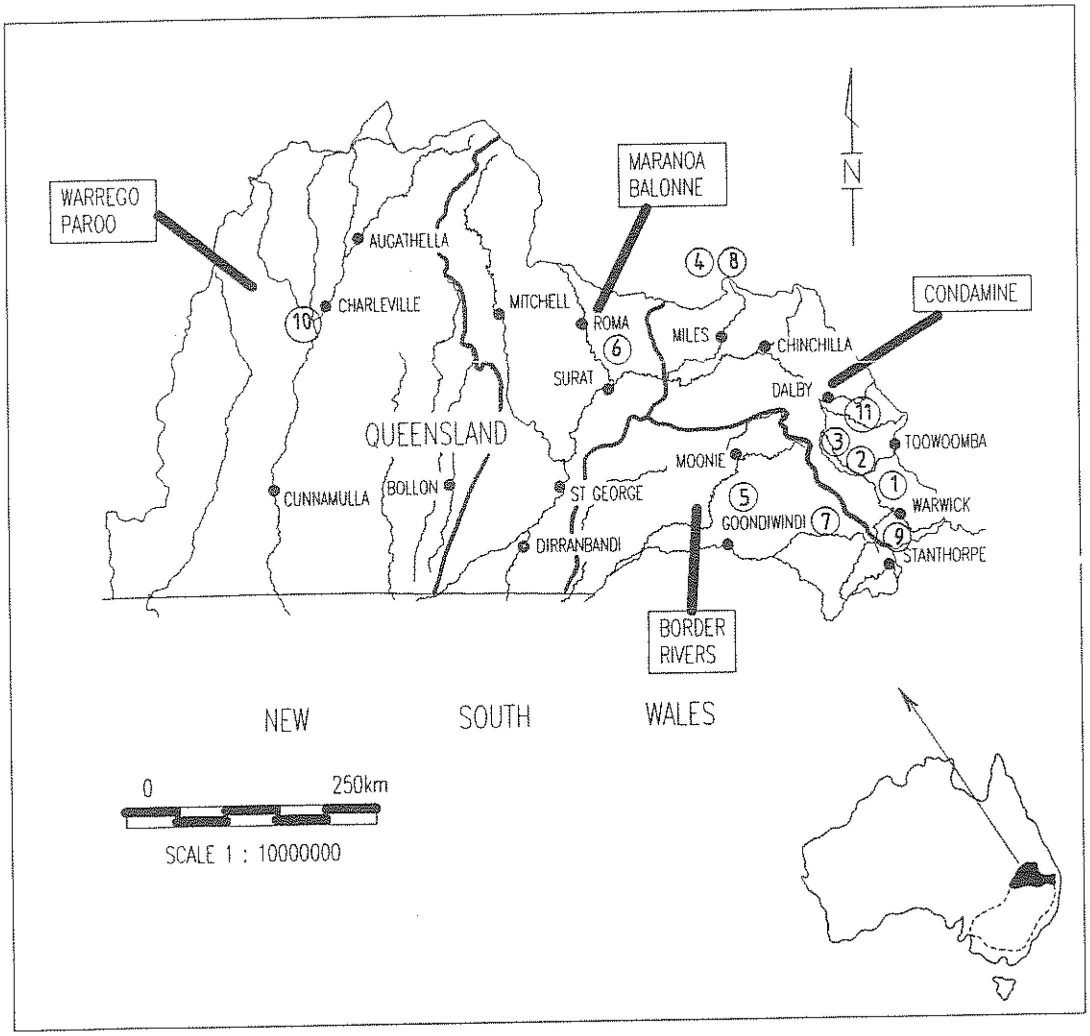
Additionally, the time taken for nutrients and other chemicals to move below the root zone to the water table can be substantial (maybe centuries). So the current conditions in the groundwaters may bear little resemblance to those in the future. Thus, information on amounts and rates of downward water and chemical movement is required to formulate *complete, long-term* catchment management plans for minimising the loss of applied nutrients and other chemicals from agricultural catchments to where they are not wanted.

The downward movement of chemicals has been measured using techniques involving determination of the rates of water movement below the root zone and to the water table. This has proved difficult. Recently tracer techniques for estimating these water fluxes have been developed and applied in groundwater investigations (Thorburn *et al.* 1991, Kennett-Smith *et* al. 1994). These same methods, with additional measurements of

Table 1 Catchment details

Site	Location	Soil type	Land use	Area, ha
1	Goomburra	Deep clay	Rain forest	1
2	Greenmount	Cracking clay	Crop, pasture, forest	6 * 1
3	Pittsworth	Cracking clay	Crop, pasture, forest	Nested 3, 27, 243, 5000
4	Theodore	Brigalow clay	Crop, pasture, forest	3 * 10-16
5	Goondiwindi	Brigalow clay	Crop	Nested 10, 100, 870
6	Wallumbilla	Red brown earth	Crop, pasture, forest	3 * 3
7	Inglewood	Solodic (Traprock)	Pasture, forest	2 * 10
8	Theodore	Solodic (Sandstone)	Crop	2 * 1
9	Stanthorpe	Solodic (Granite)	Crop, pasture, forest	3 * 5-10
10	Charleville	Red earth	Pasture, timber	3 * 1
11	Oakey Ck	Mixture	Urban, mixed rural	Nested 4600, 14200, 200000

Map 1 Location of catchments



chemical concentrations, can be applied for estimating downward chemical movement. Additionally, information can be gained on times taken for chemicals to move to the water table in different land use/soil type combinations using some of these approaches (Jolly *et al.* 1989).

In this study, these techniques will be used to measure rates of movement of water and mobile nutrients below the root zone under a range of land uses (forest, pasture, crops) and the main soil types in the upper MDB and to assess the effect of different land uses and farming systems on the downward losses of nutrients to the groundwater. In addition, more traditional hydrological techniques (analysis of groundwater levels and chemistry) will be applied to establish likely recharge rates in the long-term past. Models of nutrient movement will then be developed to evaluate the impact of different catchment management options on nutrient movement from the root-zone.

MODELLING FRAMEWORK

A generic spatial modeling framework using ADVISE software (Lau *et al*,1994) to interactively link the models mentioned above with a GIS for scenario analyses and decision support applications will be constructed.

About ADVISE:

Many of the current visualisation packages are designed for viewing static data files. However, the next generation of visualisation tools should incorporate advances such as parallel processing, computational steering within models, high degree of user-interaction, intuitive graphical interface and modular components, all within an integrated development environment. ADVISE was developed to illustrate some of the concepts of integrating simulation models with visualisation resources such as a vector supercomputer, a parallel computer or some network of machines.

ADVISE acts as a communication interface between the client, typically a graphics device, and the server, a computing resource such as a vector supercomputer, a parallel computer, or some network of machines.

Basically it is a spatial modelling application with the following features:

- client/server approach formed by separating the model and visualisation components onto machines best suited for each stage. The model could further exploit parallelism by running on a high performance computer.
- a simple protocol for controlling the models and visualising the data efficiently.
- remote models can be written in Fortran or C.
- transparent remote module placement and data transfer using PVM, a message passing library designed for accessing heterogeneous networks of computers.
- user friendly control mechanism with the user directly controlling the progress of the simulation and having interactive choice of variables to view.

ADVISE gives the user flexibility to run models on a variety of hardware platforms without being constrained to a possibly limiting environment. It has, for example, been ported to run on the Intel Paragon (Rezny,1994), and it is intended to port this to the newly acquired 7 Gigaflop Silicon Graphics Power Challenge, recently installed at the University of Queensland.

GIS/VISUALISATION

A user-friendly presentation interface which will give a three dimensional visualisation of model output is being produced. The involves taking output produced from the ADVISE modelling environment and draping it over an existing digital terrain model of the catchment. This will be done using a standard visualisation package, (CLRview, developed by the Centre for Landscape Research, University of Toronto, Canada).

Using this package, fly-throughs of the output of the models will be possible. For example, it will be possible to simulate travel down any road in the catchment viewing predictions of flood size. The operator will be able to stop the 'fly-through' at any time and interact with the data.

Operations intended to be demonstrated will be -

- doing queries back to the ADVISE data sets.
- doing projections of data sets from other geographic information systems for the catchment, for example, a Digital Cadastral Data Base.
- doing queries of other data sets based on the current geographic position.

Other possibilities that will be explored will be passing parameters back to the models running in ADVISE. In other words, we should be able to stop the models in time and move in space, and also stop in space and move the model in time.

OUTCOMES

The work explained has the following objectives:

- development and distribution of a generic and widely applicable spatial modelling framework for analysing catchment management options and their potential impacts on stream water quality.
- a customised decision support information system and maps on water quality scenarios for alternative cropping and land use practices and for contrasting weather sequences in an upper Murray-Darling Basin catchment.

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